Water Yields from Small Forested Watersheds

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Water use has grown rapidly in this country. The increasing population and expanding demand for goods assures a continuing growth in use. There's little doubt that small watersheds will be called upon to fill a part of this need. The authors of this article report a study which shows some of the possibilities and problems in using certain small forested watersheds as a source of supply.

THROUGHOUT the United States, cities and farms are finding it increasingly difficult to meet their water needs during certain times of the year. There are several reasons for this: Populations have increased, each individual uses more water today, industry uses a great deal more water every year, and in some areas the water table has dropped because of excessive drain upon it. As a result of this increased need for water, there is a constant search for new sources of supply. Unless care and judgment are used in selecting the watersheds to meet this growing demand, costly mistakes can be made.

Research Points the Way

A knowledge of the relationship between rainfall and runoff for each season of the year is one of the key factors in planning for an adequate water supply. In a recent paper in this JOURNAL,[1] Harrold presented some interesting water-yield data based largely on work at the Watershed Hydrology Research Station at Coshocton, Ohio. He also pointed out the need for additional information from other areas. This paper presents rainfall and runoff data from small forested watersheds in West Virginia and outlines a method of using such data in planning for water supplies.

On the Fernow Experimental Forest near Parsons, West Virginia, the U. S. Forest Service is making continuous measurements of precipitation and runoff on five gauged watersheds. These small watersheds, which range in size from 40 to 95 acres, are covered with a good hardwood forest. The slopes are steep. The soils are medium-textured and over two feet in depth.

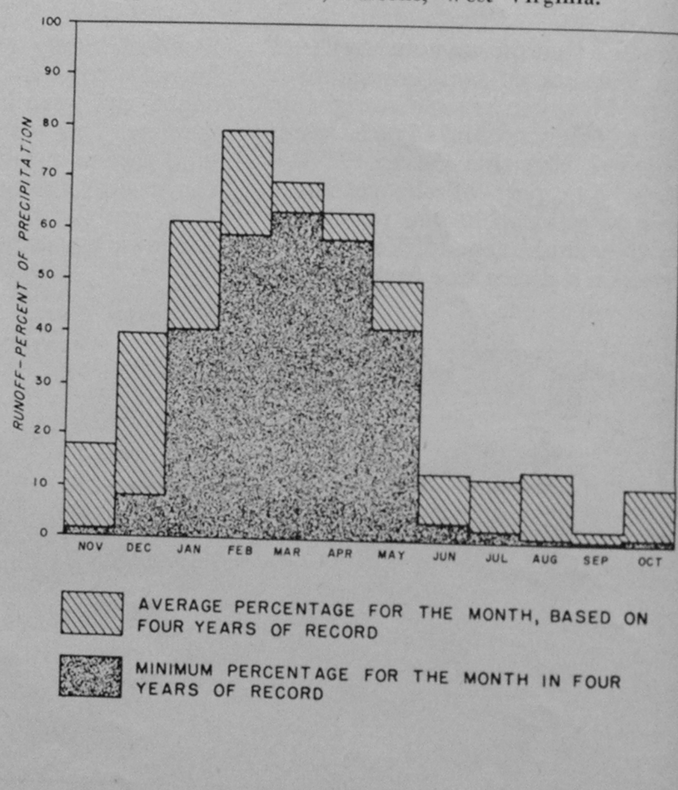
The underlying rocks are sandstone or shale. There is little deep seepage. Since the cut-off walls are extended to bedrock, almost all the outflow from the watershed is measured at the weir. Most of the precipitation is received in the form of rain; there is seldom any large hold-over of snow from one month to the next.

Rainfall-Streamflow Pattern

From four years of record, a pattern of the relationship between rainfall and streamflow, by season and month, is emerging. The general relationship between rainfall and runoff is obvious. Other things being equal, the more rain that falls, the more water that runs down the streams.

However, there is a great difference in the proportion of rainfall that finds its way into the stream with the season and month of the year. Figure 1 gives a generalized picture of the disposition of the monthly rainfall to runoff.

FIGURE 1. Disposition of monthly precipitation, Fernow Experimental Forest, Parsons, West Virginia.



[1] *Harrold, Lloyd L. Upstream surface-water supplies—need for facts.* JOUR. SOIL AND WATER CONSERV. *11: 174-176. 1956.*

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Forest cover helps even out the discharge of water from most watersheds. Without adequate cover, discharge hits high but short peaks soon after rainfall. But with good cover, flow of water is more stable.

The water year is divided into two seasons: the growing season (from May 1 to October 31) and the dormant season (from Nov. 1 to April 30). Disposition of rainfall by season is shown in Table 1. In the four years of record, between 16 and 30 percent of the precipitation reached the stream during the growing season. The dormant season is generally a time of water plenty: from 48 to 72 percent of the rainfall became streamflow. The difference in streamflow lies in the differences in heat energy available for evaporation in the different seasons and the associated greater use of water by vegetation when it is in full leaf than when it is dormant.

TABLE 1. Disposition of precipitation by season.

Season	Average rainfall	Average runoff		Runoff for Driest year
	Inches	*Inches*	*Percent*	*Percent*
Dormant season (Nov. 1 to April 30)	28.8	17.0	59.0	48.0
Growing season (May 1 to Oct. 31)	27.8	6.8	24.5	16.5

Monthly Variation

Though the summaries by growing season and dormant season show a large seasonal difference in the proportion of rainfall that enters the stream, more detailed information is usually necessary for planning purposes. There is a much wider range of streamflow on a monthly basis (Table 2). These fluctuations emphasize one of the water problems in the area—the wide range of available water supply.

At the beginning of the growing season, in May, the average runoff is around 50 percent of rainfall, giving the condition illustrated on page 59. As the growing season progresses, the percentage drops until in August it is sometimes down to around one percent of rainfall, with resultant drying of stream beds.

September and October are generally the driest months. Rainfall is lower on the average during these months, and a smaller proportion of it gets into the stream. The summer-dried soil holds most of it. During dry years some streams from watersheds up to 75 acres in size, underlain by sandstone and shale, will dry up entirely for several days to several weeks. This is more likely to occur where the soils are shallow.

Beginning with the dormant season in November, the wet cycle starts. The percentage of rain that runs off in November is still low. November rains are mostly consumed in wetting the soil after the dry October weather. Some years only one percent of the rainfall reaches the stream. December through February shows a continual increase in water available as streamflow. From January through April, 60 percent or more of the precipitation that falls generally gets into streamflow.

Yearly Differences

Of course, these average relationships will not hold under conditions of extremely abnormal climatic conditions. Unusual weather, such as 15 inches of rain in

Table 2.—Monthly runoff as a percent of precipitation. Fernow Experimental Forest, Parsons, W. Va.

Item	Runoff—percent of precipitation											
	Nov.	Dec.	Jan.	Feb	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.
Mean	17.9	39.6	61.6	79.0	69.2	63.4	50.3	13.3	12.4	14.0	2.5	11.0
Highest	62.1	74.8	81.3	96.3	77.5	69.0	53.8	38.8	23.8	28.0	6.9	41.1
Lowest	1.0	8.0	40.2	58.8	63.7	58.1	40.9	3.7	2.1	.7	.6	.9

September or one inch of rain in May, will upset the pattern. Hurricane rains in August and October have caused the high runoff values shown in Table 2.

Table 2 shows the extremes in monthly runoff recorded during the four years of record. These can serve as guides in planning a water supply. The longer the period of observation, the more reliable the data. Fortunately, during the period of observation, a very dry year and a very wet year were sampled.

Applying the Data

This information can be applied by users of streamflow from areas similar to the Fernow Forest but without streamflow records to give general estimates of potential streamflow based on rainfall records. For instance, the data presented in this paper can be used to estimate available streamflow for areas of similar vegetation, soils, and climate where long streamflow records are not available and information is desired by such users as:

(1) A city manager planning a water supply from a forested watershed. He needs to know how much runoff he can count on during dry periods from areas of different sizes. Then he can weigh the relative merits of using a larger watershed against building a larger reservoir.

(2) A small industry considering several locations for a plant. There are no records of streamflow for these areas. How can he determine which is the best?

(3) A man building a farm pond. He needs to know minimum flows as well as maximum flows from the feeder stream. He is especially interested in how long the feeder is likely to flow—or whether it will dry up altogether at times.

Following is a theoretical example:

A small industry has located near a stream coming out of a 600-acre forested watershed. The company needs a minimum of 200,000 gallons of water per month. The company has three alternatives in planning its water supply: (1) depend on the stream without damming, (2) build a reservoir, or (3) pipe water in from another source. Which is the best solution?

Average Precipitation

First, from Table 2, they might assume the average monthly streamflow expressed as a percentage of precipitation for the month of lowest streamflow. This is September; it averages 2.5 percent for the four-year record.

Then, reference to U. S. Weather Bureau records for the locality would indicate the average precipitation for that month. Assume the average rainfall was three inches. Two and a half percent of three inches gives a monthly runoff of 0.075 inches. When converted to gallons for the 600-acre watershed, this is 1,221,930 gal-

This photo shows a stream in a forested watershed during a period of low water. The same spot is shown in the photo on page 59.

lons. This means that streamflow for the average year would be more than adequate.

However, suppose the industry were interested in guaranteeing a supply for every year—then they would read the minimum monthly streamflow from Table 2. This is 0.6 percent as compared to the average of 2.5 percent.

Reference to Weather Bureau records for the locality will give the minimum rainfall that has been recorded for the month. Assume this is 0.5 inch. Then, going through the same computations, this gives 48,877 gallons for the driest month. This means that streamflow alone would not meet the need during the driest periods likely to occur. A small, inexpensive reservoir might well provide for the rare times when streamflow was deficient; laying miles of water line might not be necessary.

Limitations of the Data

The method described can help the potential user decide whether or not he has a water-supply problem. It can help him determine if his potential supply is so great that no further investigation is necessary or if his potential supply is so small that he needs to look elsewhere for water. Also, it may point out the need for more detailed investigations before making a final decision.

Reliable results cannot normally be assured by using only four years of record. Minimum flows usually become smaller as more data are accumulated. However, it is reassuring to note that the Weather Bureau record of the station closest to the Fernow Forest shows that only 1.6 percent of the months in the last 56 years had less precipitation than the driest month of the 4-year record period. Since one of the driest years of record was sampled, estimates of minimum flows are far more reliable than could normally be expected with such a short record.

A large city or industry might want more complete information on a particular watershed than can be obtained from this type of data. Long-term records of runoff collected by the U. S. Geological Survey give such information for many streams. However, where such data are not available, the method outlined above, utilizing short-term streamflow and long-term rainfall records, can answer some basic questions.

It must be recognized that runoff per unit area has been shown in many cases to vary somewhat with size of drainage area. Therefore care must be taken not to expand data from small watersheds to very large areas.

Differences in soils, topography and geology, as well as rainfall, must also be considered. For example, the water-yield data found on the Fernow would definitely not be applicable to an area underlain by limestone.

This is the same spot on the same stream shown on page 58. However, this photo was taken during a period of abundant water.